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(54) **GAS ANALYZER**

(57) A gas analyzer configured to measure a concentration of a measurement target component contained in a gas sample includes: a light source unit for emitting light including an absorption wavelength of the measurement target component; a cell for encapsulating the gas sample; a light-receiving element for obtaining a radiation spectrum of the light that has passed through the cell; a signal processing circuit for processing a received-light signal of the light-receiving element, and measuring a concentration of the measurement target component; and an adjustment unit which is arranged between a light path from the light source unit to the light-receiving element, and for adjusting a characteristic of the radiation spectrum of the light for every wavelength.

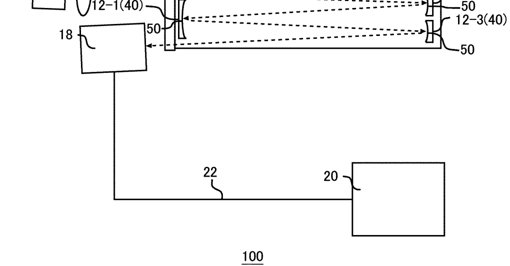

FIG.1

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Description

BACKGROUND

1. TECHNICAL FIELD

[0001] The present invention relates to a gas analyzer.

2. RELATED ART

[0002] Conventionally, a gas analyzer that utilizes spectrum analyzation has been known (for example, Patent Document 1).

[0003] Patent Document 1: Japanese Patent Application Publication No. 2001-188043

SUMMARY

[0004] It is preferable for a gas analyzer to be able to precisely measure a gas concentration.

[0005] In order to achieve the above, a first aspect of the present invention provides a gas analyzer. The gas analyzer may measure a concentration of a measurement target component contained in a gas sample. The gas analyzer may include a light source unit. The light source unit may emit light including an absorption wavelength of the measurement target component. The gas analyzer may include a cell. The cell may encapsulate the gas sample. The gas analyzer may include a light-receiving element. The light-receiving element may obtain a radiation spectrum of light that has passed through the cell. The gas analyzer may include a signal processing circuit. The signal processing circuit may process a received-light signal of the light-receiving element. The signal processing circuit may measure a concentration of the measurement target component. The signal processing circuit may include an adjustment unit. The adjustment unit may be arranged on a light path from the light source unit to the light-receiving element. The adjustment unit may adjust a characteristic of a radiation spectrum of light for every wavelength.

[0006] A reflecting mirror may be disposed inside the cell. The reflecting mirror may be arranged such that light introduced into the cell is reflected for multiple times inside the cell. The adjustment unit may be the reflecting mirror.

[0007] Light emitted by the light source unit may have a maximum intensity in a radiation spectrum in a certain wavelength. The light-receiving element may obtain an intensity of light in a plurality of wavelengths. A reflectance of the reflecting mirror in a certain wavelength may be lower than an average reflectance taken in a wavelength range from a minimum wavelength to a maximum wavelength among a plurality of wavelengths at the light-receiving element.

[0008] A plurality of reflecting mirrors may be disposed inside the cell. In a reflection area of at least one reflecting mirror, a reflectance in at least two wavelengths may be lower than the average reflectance.

[0009] At least one reflecting mirror may be arranged outside the cell.

[0010] The light-receiving element may receive a radiation spectrum of light that has passed through the cell. The light-receiving element may output a received-light signal. The signal processing circuit may measure a concentration of the measurement target component based on one or more received-light signals output by the light-receiving element depending on light that enters into the light-receiving element in a predefined measurement period. The measurement period may include two or more flashes of the light source unit.

[0011] The light-receiving element may be exposed to light for multiple times in the measurement period. The signal processing circuit may integrate intensities of light in a plurality of received-light signals in the measurement period.

[0012] The signal processing circuit may integrate intensities of light in the plurality of received-light signals for every wavelength.

[0013] The signal processing circuit may change the integration of received-light signals in a maximum wavelength in the radiation spectrum of the light.

[0014] The signal processing circuit may average integration signals obtained by integrating the plurality of received-light signals, and measure a concentration of the measurement target component.

[0015] The light exposure period for the light-receiving element may be changed based on the intensity of the radiation spectrum of the light.

[0016] The light-receiving element may be exposed to light for once in the measurement period. The light exposure period for the light-receiving element may include two or more flashes of the light source unit.

[0017] The light source unit may be a flash lamp.

[0018] The summary clause does not necessarily describe all necessary features of the embodiments of the present invention. The present invention may also be a subcombination of the features described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Fig. 1 illustrates one example of a gas analyzer 100 according to an embodiment.

Fig. 2 illustrates one example of a radiation spectrum of light 6 emitted by a light source unit 2.

Fig. 3 illustrates a relationship between an intensity of the light 6 in a predefined wavelength and a measurement error.

Fig. 4 illustrates one example of a reflection characteristic of a reflecting mirror 12.

Fig. 5 illustrates one example of a radiation spectrum of light 6 emitted by a cell 10.

Fig. 6 illustrates another example of the reflection characteristic of the reflecting mirror 12.

Fig. 7 illustrates another example of a reflection area 50 of the reflecting mirror 12.

Fig. 8 illustrates an example of structure of a gas analyzer 200 according to another embodiment.

Fig. 9 illustrates an example of structure of a gas analyzer 300 according to yet another embodiment.

Fig. 10 illustrates one example of a lamp operation cycle, a flash cycle, and a light exposure period.

Fig. 11 illustrates one example of a lamp operation cycle, a flash cycle, and a light exposure period according to a comparative example.

Fig. 12 illustrates a differential absorbance of every wavelength when a number of integrations is changed.

Fig. 13 illustrates comparison of intensities of radiation spectra of the light 6 between an example illustrated in Fig. 10 and the comparative example illustrated in Fig. 11.

Fig. 14 illustrates another example of the lamp operation cycle, the flash cycle, and the light exposure period.

Fig. 15 illustrates an example of structure of a gas analyzer 400 according to another embodiment.

Fig. 16 illustrates a relationship between a number of irradiations of the light source unit 2 in a measurement period and a measurement error.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0020] Hereinafter, the present invention will be described through embodiments of the invention, but the following embodiments do not limit the invention according to the claims. In addition, not all combinations of features described in the embodiments are essential to the solution of the invention.

[0021] Fig. 1 illustrates one example of a gas analyzer 100 according to an embodiment. The gas analyzer 100 includes a light source unit 2, a collimator lens 4, a cell 10, a reflecting mirror 12, a light-receiving element 18, a signal processing circuit 20, and a communication line 22. The gas analyzer 100 is configured to measure a concentration of a measurement target component contained in a gas sample 30. In the present example, the gas analyzer 100 measures the concentration of the measurement target component by means of differential optical absorption spectroscopy (DOAS) with which a variation in the light source unit 2 can be removed. By using the differential optical absorption spectroscopy, the concentration of the measurement target component can be measured only with a small-scale fluctuating component in an absorption spectrum, which can provide a stable measurement.

[0022] The gas sample 30 is a gas containing the measurement target component. In the present example, the gas sample 30 is an exhaust gas that flows in a flue. The measurement target component is a measurement target of the gas analyzer 100, e.g., SO_3. The measurement target component may also be SO_2, SO_x, NO_2, NO_3, NO, NH_3, or NO_x.

[0023] The light source unit 2 emits light 6. In the present example, the light source unit 2 emits light 6 including an absorption wavelength of the measurement target component. By way of example, the light source unit 2 is a flash lamp that can control flash-time to be extremely short. The light source unit 2 may be a xenon flash lamp. By using the xenon flash lamp as the light source unit 2, the light 6 can be stably emitted. It is preferable for the light source unit 2 of the present example to flash at a regular flash cycle.

[0024] The collimator lens 4 collects light 6 emitted from the light source unit 2. The light 6 collected by the collimator lens 4 is then irradiated to a cell window 8 of the cell 10.

[0025] The cell 10 is for encapsulating the gas sample 30. The cell 10 has the cell window 8, a gas sample inlet port 24, and a gas sample outlet port 26. The cell window 8 is disposed facing the collimator lens 4, and is irradiated with the light 6. The light 6 is introduced into the cell 10 through the cell window 8. The gas sample inlet port 24 introduces the gas sample 30 to the cell 10. The gas sample outlet port 26 discharges the gas sample 30 from the cell 10. The gas sample inlet port 24 and the gas sample outlet port 26 are connected to the flue, for example. When analyzing a concentration of the measurement target component contained in the gas sample 30, the gas sample 30 may be introduced into the cell 10 through the gas sample inlet port 24. After the analyzing, the gas sample 30 may be discharged from the cell 10 through the gas sample outlet port 26. The cell 10 may have a pump for introducing or discharging the gas sample 30. The cell 10 may have a filter for removing dust in the gas sample 30, and for introducing this gas sample 30 into the cell 10.

[0026] The reflecting mirror 12 is disposed inside the cell 10. A plurality of reflecting mirrors 12 may be disposed inside the cell 10. In the present example, a reflecting mirror 12-1, a reflecting mirror 12-2, and a reflecting mirror 12-3 are disposed inside the cell 10. In Fig. 1, the reflecting mirror 12-1 is disposed on a side having the gas sample inlet port 24, and the reflecting mirrors 12-2 and 12-3 are disposed on a side having the gas sample outlet port 26. Although the reflecting mirrors 12-2 and 12-3 are separately illustrated in Fig. 1, the reflecting mirrors 12-2 and 12-3 may also form an integrated mirror. The cell 10 may be in a form of a white cell. The side having the gas sample inlet port 24 refers to an area inside the cell 10 which is on a side closer to the gas sample inlet port 24 relative to a center of the cell 10, and the side having the gas sample outlet port 26 refers to an area inside the cell 10 which is on a side closer to the gas sample outlet port 26 relative to the center of the cell 10.

[0027] The reflecting mirror 12 is arranged such that the light 6 introduced in the cell 10 is reflected for multiple times inside the cell 10. More specifically, the reflecting mirror 12 is arranged such that the light 6 is reflected at least once in each of the area on the side having the gas sample inlet port 24 and the area on the side having the gas sample outlet port 26. The reflecting mirror 12 is arranged such that the light 6 is reflected for m times (m is an integer being one or more) in the area on the side having the gas sample inlet port 24, and reflected for m+once in the area on the side having the gas sample outlet port 26. In this case, the light 6 is emitted outside the cell 10 from the cell window 8. In the example of Fig. 1, the reflecting mirror 12 is arranged such that the light 6 is reflected for three times. A number of reflections is not limited to three. By means of adjusting the reflecting mirror 12, the light 6 may be reflected for three times or more. The number of reflections may also be 15 times. By means of increasing the number of reflections, a length of a light path of the light 6 can be longer, so that a concentration can be precisely measured even with a small amount of the measurement target component. The reflecting mirror 12 may also function as an adjustment unit 40 described below. The reflecting mirror 12 has a reflection area 50. The reflection area of the reflecting mirror 12 is where the reflecting mirror 12 reflects the light 6.

[0028] The light-receiving element 18 is for obtaining a radiation spectrum of the light 6 that has passed through the cell 10. The light-receiving element 18 is for obtaining an intensity of the radiation spectrum of the light 6 for every wavelength. The light-receiving element 18 may have a filter. In the present example, the filter of the light-receiving element 18 spectrally disperses light having a wavelength in a range of from 200 nm to 400 nm only. The filter may disperse the light 6 into a plurality of wavelength bands. In this case, the light-receiving element 18 can obtain an intensity of the light 6 for every wavelength. The light-receiving element 18 may obtain an intensity of the light 6 in a plurality of wavelengths. By way of example, the light-receiving element 18 is a CMOS (Complementary Metal Oxide Semiconductor) line sensor. The radiation spectrum of the light 6 obtained by the light-receiving element 18 is sent as a received-light signal to the signal processing circuit 20.

[0029] The signal processing circuit 20 is for processing the received-light signal of the light-receiving element 18. The signal processing circuit 20 is for measuring the concentration of the measurement target component of the gas sample 30 based on the received-light signal of the light-receiving element 18. The signal processing circuit 20 may measure the concentration of the measurement target component by obtaining a change in the intensity of the light 6 in an absorption wavelength of the measurement target component. The signal processing circuit 20 is connected to the light-receiving element 18 through the communication line 22. Although the signal processing circuit 20 and the light-receiving element 18 are connected with a wire in the example of Fig. 1, they may be wirelessly connected instead.

[0030] Fig. 2 illustrates one example of the radiation spectrum of the light 6 emitted by the light source unit 2. In Fig. 2, a wavelength is represented along a horizontal axis, and an intensity of the light 6 is represented along a vertical axis.

[0031] In Fig. 2, when the wavelength is 230 nm, the intensity of the light 6 is 0.20 or more (see the area R1). When the wavelength is 330 nm, the intensity of the light 6 is 0.05 or less (see the area R2). The intensity in the area R1 is four times as high as the intensity in the area R2, or more. Therefore, there is a difference in intensities in a range of light received by the light-receiving element 18 (in a range where the wavelength is from 200 nm to 400 nm).

[0032] Fig. 3 illustrates a relationship between an intensity of the light 6 in a predefined wavelength and a measurement error. It is indicated that the smaller a value in a vertical axis in Fig. 3 is, the fewer the measurement errors are. In Fig. 3, as the intensity of the light 6 becomes higher, the measurement error is reduced more. In other words, as the intensity of the light 6 becomes higher, measurement precision improves more. One cause of the measurement error may be considered as a thermal noise in the light-receiving element 18, a stray light that enters into the light-receiving element 18, or the like. The higher the intensity of the light 6 is, the higher a signal-to-noise ratio can be.

[0033] A dynamic range of the CMOS line sensor used for the light-receiving element 18 is generally about 100 dB, which is, when applied to the intensity of the light 6 represented along a horizontal axis in Fig. 3, 65535 is the maximum value. As illustrated in Fig. 2, there is about a four times difference in intensities in the range of the light received by the light-receiving element 18 (in the range where the wavelength is from 200 nm to 400 nm). When an upper limit value, e.g. 65535, of the dynamic range of the light-receiving element 18 is applied to the intensity in the area R1, a measurement value of the light-receiving element 18 which corresponds to a radiation intensity in the area R2 is 16383.75 (65535÷4) or less. That is, if there is a difference in intensities of the light 6 in the plurality of wavelengths, the dynamic range of the light-receiving element 18 becomes small in some wavelength among the plurality of wavelengths, and measurement precision in this wavelength will be degraded. Be-cause of that, when measuring intensities of the light 6 in the plurality of wavelengths, it is preferable to reduce the difference in the intensities of the light 6 as much as possible between each measurement wavelength.

[0034] In the present example, the gas analyzer 100 includes the adjustment unit 40. The adjustment unit 40 is for adjusting a characteristic of the radiation spectrum of the light 6 for every wavelength. The adjustment unit 40 adjusts the radiation spectrum of the light 6 that has been radiated from the light source unit 2. The adjustment unit 40 is arranged on a light path from the light source unit 2 to the light-receiving element 18. In the present example, the adjustment unit 40 is the reflecting mirror 12. By adjusting the reflection characteristic at the reflecting mirror 12 for every wavelength, the radiation spectrum of the light 6 transmitting in the cell 10 can be adjusted. Since the gas analyzer 100 includes the adjustment unit 40 for adjusting the characteristic of the radiation spectrum of the light 6 for every wavelength, a difference in intensities of radiation spectra of the light 6 can be reduced, and thereby measurement precision can be improved.

[0035] Fig. 4 illustrates one example of the reflection characteristic of the reflecting mirror 12. Fig. 4 illustrates a reflectance of the reflecting mirror 12 for every wavelength. In the present example, the reflecting mirrors 12-1, 12-2, and 12-3 have the reflection characteristic illustrated in Fig. 4. All reflection areas 50 of the reflecting mirror 12-1, all reflection areas 50 of the reflecting mirror 12-2, and all reflection areas 50 of the reflecting mirror 12-3 may have the reflection characteristic illustrated in Fig. 4.

[0036] As illustrated in Fig. 4, a certain wavelength $\lambda 1$ has a reflectance lower than an average reflectance in a predefined wavelength range at the reflecting mirror 12. For example, the predefined wavelength range may be, among the plurality of wavelengths measured at the light-receiving element 18, a range from a minimum wavelength to a maximum wavelength. The predefined wavelength range may also be a wavelength range where the light-receiving element 18 has sensibility. The predefined wavelength range may also be a wavelength range where the light 6 emitted by the light source unit 2 has an intensity. In the example of Fig. 4, the average reflectance is an average of reflectances within a range of from 200 nm to 400 nm. In the example of Fig. 4, the average reflectance is a value close to 0.9. The certain wavelength $\lambda 1$ has a reflectance lower than the average reflectance. By way of example, the certain wavelength $\lambda 1$ is a wavelength having a maximum intensity in the radiation spectrum of the light 6 emitted by the light source unit 2. The reflectance in a range of this wavelength may be a local minimum value in the certain wavelength $\lambda 1$. In addition, the reflectance in the certain wavelength $\lambda 1$ may be lower than a median value between the average value and the local minimum value in the range of this wavelength. By way of example, the certain wavelength $\lambda 1$ is 230 nm. In the certain wavelength $\lambda 1$ having the maximum intensity of the radiation spectrum of the light 6 emitted by the light source unit 2, an intensity of light reflected at the reflecting mirror 12 can be reduced, thereby a difference in intensities of the radiation spectra of the light 6 received by the light-receiving element 18 can be reduced.

[0037] An emitted light intensity in the wavelength λ in the light 6 emitted from the cell 10 is referred to as $I_{\lambda out}$, a number of times to be reflected at the reflecting mirror 12 inside the cell 10 is referred to as n times, an incident light intensity in the wavelength λ in the light 6 that enters into the cell 10 is referred to as $I_{\lambda in}$, and a reflectance of the wavelength λ is referred to as R_λ. The reflectance R_λ is lower than one. The emitted light intensity $I_{\lambda out}$ is represented in the following equation 1. As represented in the following equation 1, the emitted light intensity $I_{\lambda out}$ can be reduced by increasing n.

[EQUATION 1] $$I_{\lambda out} = I_{\lambda in} \times R_\lambda^{\,n}$$

[0038] The reflection characteristic of the reflecting mirror 12 can be adjusted by depositing a dielectric multi-layer on the reflecting mirror 12. By means of adjusting a film thickness, material, layer structure and the like of the dielectric multi-layer and thereby improving a reflectance other than the reflectance of the certain wavelength $\lambda 1$, the reflectance of the certain wavelength $\lambda 1$ can become relatively low. The dielectric multi-layer may be partially disposed in the reflection area of the reflecting mirror 12.

[0039] Fig. 5 illustrates one example of the radiation spectrum of the light 6 emitted by the cell 10. In Fig. 5, a wavelength is represented along a horizontal axis, and an intensity of the light 6 is represented along a vertical axis. As illustrated in Fig. 5, the intensity of the light 6 is weakened in the vicinity of a wavelength of 230 nm. Since the adjustment unit 40 is disposed inside the cell 10, a difference in intensities of the radiation spectra of the light 6 can be reduced, and thereby measurement precision can be improved.

[0040] Fig. 6 illustrates another example of the reflection characteristic of the reflecting mirror 12. The reflection characteristic may be a reflectance being lower than an average reflectance in a plurality of certain wavelengths. The reflection characteristic in Fig. 6 is a reflectance being lower than the average reflectance in not only the certain wavelength $\lambda 1$ but also in a certain wavelength $\lambda 2$. By way of example, the certain wavelength $\lambda 2$ is 370 nm. An intensity can be reduced also in the certain wavelength $\lambda 2$, and intensity can be reduced in a different certain wavelength. The reflectance in the certain wavelength $\lambda 1$ and the reflectance in the certain wavelength $\lambda 2$ may be the same, or may be different. Between two certain wavelengths, a reflectance of one certain wavelength having a higher intensity in the radiation spectrum of the light 6 emitted by the light source unit 2 may be lower than a reflectance of the other certain wavelength.

[0041] Fig. 7 illustrates another example of the reflection area 50 of the reflecting mirror 12. In Fig. 7, a reflecting mirror 12-1 has a reflection area 50-1, a reflection area 50-2, and a reflection area 50-3. The reflecting mirror 12-2 has a reflection area 50-4. The reflecting mirror 12-3 has a reflection area 50-5. In the example of Fig. 7, the light 6 reflects in the order of a light 6-1, a light 6-2, a light 6-3, a light 6-4, a light 6-5, a light 6-6, a light 6-7, and a light 6-8. In Fig. 7, a number of reflections is seven.

[0042] In the reflection area 50 of at least one reflecting mirror 12, reflectances in at least two wavelengths may be lower than the average reflectance. In the example of Fig. 7, at least one reflection area 50 of the reflecting mirror 12-1, i.e., at least one of the reflection areas 50-1, 50-2, or 50-3, may have the reflection characteristic illustrated in Fig. 6. In that case, the rest of the reflection areas 50 of the reflecting mirror 12-1, the reflection area 50-4 of the reflecting mirror 12-2, and the reflection area 50-5 of the reflecting mirror 12-3 may have the reflection characteristic illustrated in Fig. 4. Alternatively, the reflection area 50-4 of the reflecting mirror 12-2 may have the reflection characteristic illustrated in Fig. 6, and all of the reflection areas 50 of the reflecting mirror 12-1 and the reflection area 50-5 of the reflecting mirror 12-3 may have the reflection characteristic illustrated in Fig. 4. Or the reflection area 50-5 of the reflecting mirror 12-3 may have the reflection characteristic illustrated in Fig. 6, and all of the reflection areas 50 of the reflecting mirror 12-1 and the reflection area 50-4 of the reflecting mirror 12-2 may have the reflection characteristic illustrated in Fig. 4. Since at least one reflection area 50 has the reflection characteristic illustrated in Fig. 6, a number of times to be reflected with the reflection characteristic illustrated in Fig. 6 becomes less than the number of times to be reflected with the reflection characteristic illustrated in Fig. 4. Therefore, the certain wavelength $\lambda 2$ is weakened for the number of times less than the certain wavelength $\lambda 1$, and thereby an intensity of the radiation spectrum of the light 6 for every wavelength can be adjusted. All of the reflection areas 50 of the reflecting mirror 12-1, the reflection area 50-2 of the reflecting mirror 12-2, and the reflection area 50-3 of the reflecting mirror 12-3 may have the reflection characteristic illustrated in Fig. 6.

[0043] Fig. 8 illustrates an example of structure of a gas analyzer 200 according to another embodiment. The gas analyzer 200 of the present embodiment is different from the gas analyzer 100 in Fig. 1 in that the gas analyzer 200 includes a reflecting mirror 14 as the adjustment unit 40 outside the cell 10. Otherwise, configuration of the gas analyzer 200 may be the same as that of the gas analyzer 100.

[0044] At least one reflecting mirror 14 is arranged outside the cell 10, so that an intensity of a radiation spectrum of the light 6 can be reduced after being emitted from the cell 10. Thereby, without changing inner configuration of the cell 10, the intensity of the radiation spectrum of the light 6 can be easily adjusted. In this case, the reflecting mirrors 12-1, 12-2, and 12-3 may or may not function as the adjustment unit 40.

[0045] Fig. 9 illustrates an example of structure of a gas analyzer 300 according to yet another embodiment. The gas analyzer 300 includes a light source unit 2, a collimator lens 4, a cell 10, a reflecting mirror 12, a light-receiving element 118, a signal processing circuit 120, and a communication line 22. The gas analyzer 100 is configured to measure a concentration of a measurement target component contained in a gas sample 30. Configuration of the light source unit 2, the collimator lens 4, the cell 10, and the reflecting mirror 12 may be the same as that of the gas analyzer 100 in Fig. 1. Note that, the reflecting mirror 12 may be or may not be the adjustment unit 40. In the present example, the reflecting mirror 12 is not the adjustment unit 40.

[0046] The light-receiving element 118 obtains a radiation spectrum of a light 6 that has passed through the cell 10. The light-receiving element 118 obtains an intensity of the radiation spectrum of the light 6 for every wavelength. The light-receiving element 118 may have a filter. In the present example, the filter of the light-receiving element 118 spectrally disperses light having a wavelength in a range of from 200 nm to 400 nm only. By way of example, the light-receiving element 118 is a CMOS (Complementary Metal Oxide Semiconductor) line sensor. The radiation spectrum of the light 6 obtained by the light-receiving element 118 is output as a received-light signal to the signal processing circuit 120. The light-receiving element 118 is for outputting the received-light signal depending on the light 6 that enters into the light-receiving element 118 in a predefined measurement period. The measurement period is a period in which the light-receiving element 118 obtains the radiation spectrum of the light 6. The light-receiving element 118 is exposed to light for at least once during the measurement period. In the light exposure, the light 6 is irradiated onto the light-receiving element 118 during a predefined light exposure period, and the light-receiving element 118 generates, depending on an integrated intensity of the light received in this period, a received-light signal. The light exposure may be performed multiple times during the measurement period. In other words, the light-receiving element 118 may generate a plurality of received-light signals during the measurement period. The light exposure on the light-receiving element 118 may be performed by controlling an electronic shutter of the light-receiving element 118. The light exposure on the light-receiving element 118 may be performed by controlling a mechanical shutter of the light-receiving element 118.

[0047] The signal processing circuit 120 processes the received-light signal of the light-receiving element 118. The signal processing circuit 120 measures the concentration of the measurement target component in the gas sample 30 based on one or a plurality of received-light signals output by the light-receiving element 118 during the measurement period. The signal processing circuit 120 may measure the concentration of the measurement target component by obtaining a change in an intensity in an absorption wavelength of the measurement target component. The signal processing circuit 120 is connected to the light-receiving element 118 through the communication line 22.

[0048] In the present example, the measurement period is a period including two or more flashes of the light source unit 2. By means of making the measurement period include two or more flashes of the light source unit 2, intensities of a plurality of lights 6 emitted by the light source unit 2 can be integrated. For example, with a light source having a short emission period, such as a flash lamp, flash-intensities are likely to vary in every flash. In addition, a shape of a radiation spectrum of light may change in every flash. According to the present example, a measurement error caused by characteristic variations of every flash of the light source unit 2 can be reduced.

[0049] Fig. 10 illustrates one example of a lamp operation cycle, a flash cycle, and a light exposure period. In Fig. 10, the lamp operation cycle and the flash cycle are shown as T1, the light exposure period is shown as T2, and the measurement period is shown as T3. In the present example, the light exposure period T2 is three times or more of the light exposure cycle T1, and the measurement period T3 is six times or more of the light exposure cycle T1.

[0050] In the example of Fig. 10, the light-receiving element 118 is exposed to light for once in one measurement period T3. Also, the light exposure period T2 for the light-receiving element 118 is twice or more the light exposure cycle T1. In the example of Fig. 10, although there is one light exposure in the measurement period T3, the light exposure period T2 for the light-receiving element 118 is twice or more of the light exposure cycle T1. Therefore, a plurality of lights can be integrated and thereby an S/N ratio can be improved.

[0051] Fig. 11 illustrates one example of a lamp operation cycle, a flash cycle, and a light exposure period according to a comparative example. In Fig. 11, the lamp operation cycle and the flash cycle are shown as T4, the light exposure period is shown as T5, and the measurement period is shown as T6. The flash cycle T4 and the measurement period T6 are six times more of the light exposure cycle T1, and the light exposure period T5 is three times or more of the light exposure cycle T1. The light exposure period T2 and the light exposure period T5 are equal, and the measurement period T3 and the measurement period T6 are equal.

[0052] Fig. 12 illustrates a differential absorbance of every wavelength when a number of integrations is changed. In Fig. 12, the number of integrations changes in the order of from (a) to (c). As illustrated in Fig. 12, when the number of integrations increases, measurement errors are reduced. With a light source having a short emission period, such as a flash lamp, flash-intensities are likely to vary in every flash. By means of increasing the number of integrations, characteristic variations of every flash of the light source unit 2 can be averaged. Therefore, measurement errors can be reduced in the example illustrated in Fig. 10 more than the comparative example illustrated in Fig. 11.

[0053] Fig. 13 illustrates comparison of intensities of radiation spectra of the light 6 between the example illustrated in Fig. 10 and the comparative example illustrated in Fig. 11. As illustrated in Fig. 13, since the plurality of lights is integrated in the example illustrated in Fig. 10, the intensity can be higher in the example illustrated in Fig. 10 than the comparative example illustrated in Fig. 11. In addition, by means of averaging, measurement errors can be reduced in the example illustrated in Fig. 10 more than the comparative example illustrated in Fig. 11.

[0054] Fig. 14 illustrates another example of a lamp operation cycle, a flash cycle, and a light exposure period. In Fig. 14, the lamp operation cycle and the flash cycle are shown as T7, the light exposure period is shown as T8, and the measurement period is shown as T9. The flash cycle T7 is equal to the light exposure cycle T1, the light exposure period T8 is twice or more of the light exposure cycle T1, and the measurement period T9 is six times or more of the light exposure cycle T1. The measurement period T9 is equal to the measurement period T3.

[0055] The light-receiving element 118 may be exposed to light for multiple times in the measurement period T9. In Fig. 14, the light-receiving element 118 is exposed to light for twice in the measurement period T9. The signal processing circuit 120 may integrate intensities of the light 6 in a plurality of received-light signals in the measurement period T9. In Fig. 14, the signal processing circuit 120 is for integrating the intensities in two received-light signals. With configuration in which the light-receiving element 118 is exposed to light for multiple times in the measurement period T9, the S/N ratio can be improved also.

[0056] The signal processing circuit 120 may integrate intensities of the light 6 in the plurality of received-light signals for every wavelength. The light-receiving element 118 or the signal processing circuit 120 may control the measurement period, or the light exposure period for every wavelength. For example, the light-receiving element 118 may cause a light exposure time to be shorter for a wavelength having a higher intensity of the light 6. Similarly, the signal processing circuit 120 may cause a measurement period to be shorter for a wavelength having a higher intensity of the light 6. By means of changing an integration method in every wavelength, a difference in intensities of the radiation spectra of the light 6 can be reduced. Further, a signal intensity in a received-light signal can be prevented from being saturated.

[0057] The signal processing circuit 120 may also average integration signals obtained by integrating the plurality of received-light signals, and measure a concentration of the measurement target component. For example, after separately integrating wavelengths near the area R1 of Fig. 2 and wavelengths in an area other than near the area R1 of Fig. 2, an average is obtained from the number of the integrations. By means of averaging, wavelengths having a number of integrations different from each other can also be compared, and thereby concentration can be measured precisely.

[0058] The light exposure period for the light-receiving element 118 may be changed based on the intensity of the radiation spectrum of the light 6. The light exposure period for the light-receiving element 118 may be changed by the light-receiving element 118, or the signal processing circuit 120. For example, when making an intensity higher, a number of light exposures in the measurement period may be increased. By way of example, as illustrated in Fig. 14, the number of light exposures can be two.

[0059] In the example of Fig. 14, a number of flashes of the light source unit 2 in one light exposure period T8 may also be one. In this case also, the number of flashes of the light source unit 2 in one measurement period T9 is more than one. Therefore, measurement precision can be improved.

[0060] Fig. 15 illustrates an example of structure of a gas analyzer 400 according to another embodiment. The gas analyzer 400 is different from the gas analyzer 300 illustrated in Fig. 9 in that the gas analyzer 400 includes a communication line 122. Otherwise, configuration of the gas analyzer 400 may be the same as that of the gas analyzer 300.

[0061] In Fig. 15, the signal processing circuit 120 controls the number of irradiations of the light source unit 2 through the communication line 122. The number of irradiations of the light source unit 2 refers to the number of times of the light 6 to be irradiated during one measurement period. That is, controlling the number of irradiations of the light source unit 2 refers to controlling a flash cycle of the light source unit 2.

[0062] The gas analyzer 400 measures a received-light intensity P_0 of a certain wavelength at the time of when a gas concentration of the gas sample 30 is 0 ppm, and a received-light intensity P of this wavelength at the time of when the gas sample 30 is introduced into the cell 10, and then calculates an absorbance A shown in the following equation 2. As shown in the equation 2, if the received-light intensity P_0 is low, the absorbance A is greatly changed when the received-light intensity P fluctuates. In other words, if the received-light intensity P fluctuates due to a variation in flashes of the light source unit 2 when the received-light intensity P_0 is low, a measurement result for the absorbance A is greatly changed. Therefore, it is preferable for the received-light intensity P_0 to be as high as possible. On the other hand, the received-light intensity P_0 may be gradually reduced due to a temporal change of a characteristic of the light source unit 2, the light-receiving element 18, cell window 8, and the like. It is preferable to make the received-light intensity P_0 high by virtue of the signal processing circuit 120 adjusting the number of irradiations of the light source unit 2 through the communication line 122. The signal processing circuit 120 may increase the number of irradiations of the light source unit 2 when a measured received-light intensity P_0 becomes less than a predefined threshold value.

[EQUATION 2]
$$A = -\log(P/P_0)$$

[0063] Fig. 16 illustrates a relationship between a number of irradiations of the light source unit 2 in a measurement period and a measurement error. The measurement error represents a magnitude of variation in measurement results in each measurement period when a single gas sample 30 is measured in a plurality of measurement periods. As illustrated in Fig. 16, the more the number of irradiations is increased, the more measurement errors are reduced, and measurement precision can be improved.

[0064] While the embodiments of the present invention have been described, the technical scope of the present invention is not limited to the above described embodiments. It is apparent to persons skilled in the art that various alterations and improvements can be added to the above described embodiments. It is also apparent from the scope of the claims that the embodiments added with such alterations or improvements can be included in the technical scope of the present invention.

EXPLANATION OF REFERENCES

[0065]

2: light source unit;
4: collimator lens;
6: light;
8: cell window;
10: cell;
12: reflecting mirror;
14: reflecting mirror;
18: light-receiving element;
20: signal processing circuit;
22: communication line;
24: gas sample inlet port;
26: gas sample outlet port;
30: gas sample;
40: adjustment unit;
50: reflection area;
100: gas analyzer;
118: light-receiving element;
120: signal processing circuit;
122: communication line;
200: gas analyzer;
300: gas analyzer;
400: gas analyzer

Claims

1. A gas analyzer configured to measure a concentration of a measurement target component contained in a gas sample, comprising:

    a light source unit for emitting light including an absorption wavelength of the measurement target component;
    a cell for encapsulating the gas sample;
    a light-receiving element for obtaining a radiation spectrum of the light that has passed through the cell;
    a signal processing circuit for processing a received-light signal of the light-receiving element, and measuring a concentration of the measurement target component; and
    an adjustment unit which is arranged on a light path from the light source unit to the light-receiving element, and for adjusting a characteristic of the radiation spectrum of the light for every wavelength.

2. The gas analyzer according to claim 1, wherein

    a reflecting mirror is arranged and disposed inside the cell such that the light introduced in the cell is reflected for multiple times inside the cell, and
    the adjustment unit is the reflecting mirror.

3. The gas analyzer according to claim 2, wherein

    the light emitted by the light source unit has a maximum intensity in a radiation spectrum in a certain wavelength,
    the light-receiving element is for obtaining an intensity of the light in a plurality of wavelengths, and
    a reflectance of the reflecting mirror in the certain wavelength is lower than an average reflectance taken in a wavelength range from a minimum wavelength to a maximum wavelength among the plurality of wavelengths at the light-receiving element.

4. The gas analyzer according to claim 3, wherein

    a plurality of reflecting mirrors, each being identical to the reflecting mirror, is disposed inside the cell, and
    at least one of the reflecting mirrors has a reflection area in which reflectances of at least two wavelengths are lower than the average reflectance.

5. The gas analyzer according to any one of claims 2 to 4, wherein at least one of the reflecting mirrors is arranged outside the cell.

6. A gas analyzer configured to measure a concentration of a measurement target component contained in a gas sample, comprising:

    a light source unit for emitting light including an absorption wavelength of the measurement target component;
    a cell for encapsulating the gas sample;
    a light-receiving element for receiving a radiation spectrum of the light that has passed through the cell, and for outputting a received-light signal; and
    a signal processing circuit for measuring a concentration of the measurement target component based on one or more received-light signals, each being identical to the received-light signal, output by the light-receiving element depending on the light that enters into the light-receiving element in a predefined measurement period, wherein
    the measurement period is a period including two or more flashes of the light source unit.

7. The gas analyzer according to claim 6, wherein

    the light-receiving element is exposed to light for multiple times in the measurement period, and
    the signal processing circuit is for integrating intensities of the light in a plurality of received-light signals, each being identical to the received-light signal, in the measurement period.

8. The gas analyzer according to claim 7, wherein the signal processing circuit is for integrating intensities of the light in the plurality of received-light signals for every wavelength.

9. The gas analyzer according to claim 7 or 8, wherein the signal processing circuit is for averaging integration signals obtained by integrating the plurality of received-light signals, and for measuring a concentration of the measurement target component.

10. The gas analyzer according to claim 6, wherein a light exposure period for the light-receiving element is changed based on an intensity of the radiation spectrum of the light.

11. The gas analyzer according to claim 6, wherein

    the light-receiving element is exposed to light for once in the measurement period, and
    a light exposure period for the light-receiving element is a period including two or more flashes of the light source unit.

12. The gas analyzer according to any one of claims 6 to 11, further comprising:
an adjustment unit which is arranged between a light path from the light source unit to the light-receiving element, and configured to adjust a characteristic of a radiation spectrum of the light for every wavelength.

13. The gas analyzer according to any one of claims 1 to 12, wherein the light source unit is a flash lamp.

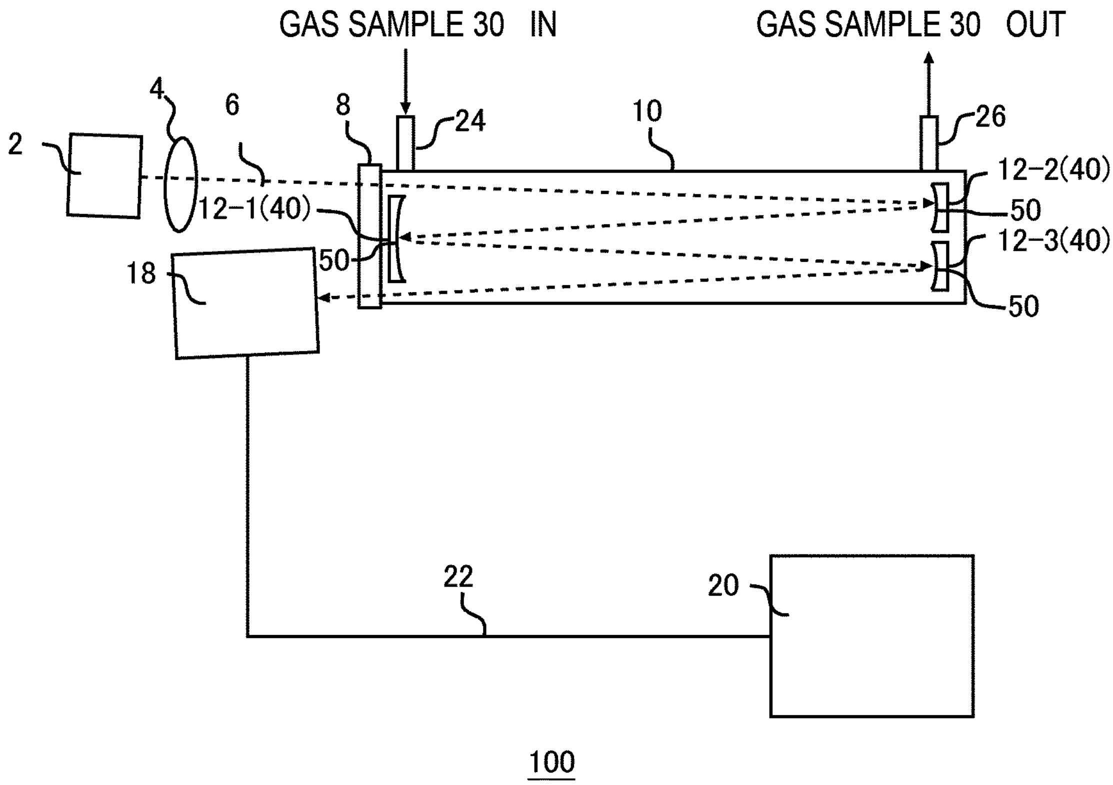
GAS SAMPLE 30 IN
GAS SAMPLE 30 OUT
4
6
8
24
10
26
2
12-2(40)
12-1(40)
50
50
12-3(40)
18
50
22
20
100

FIG.1

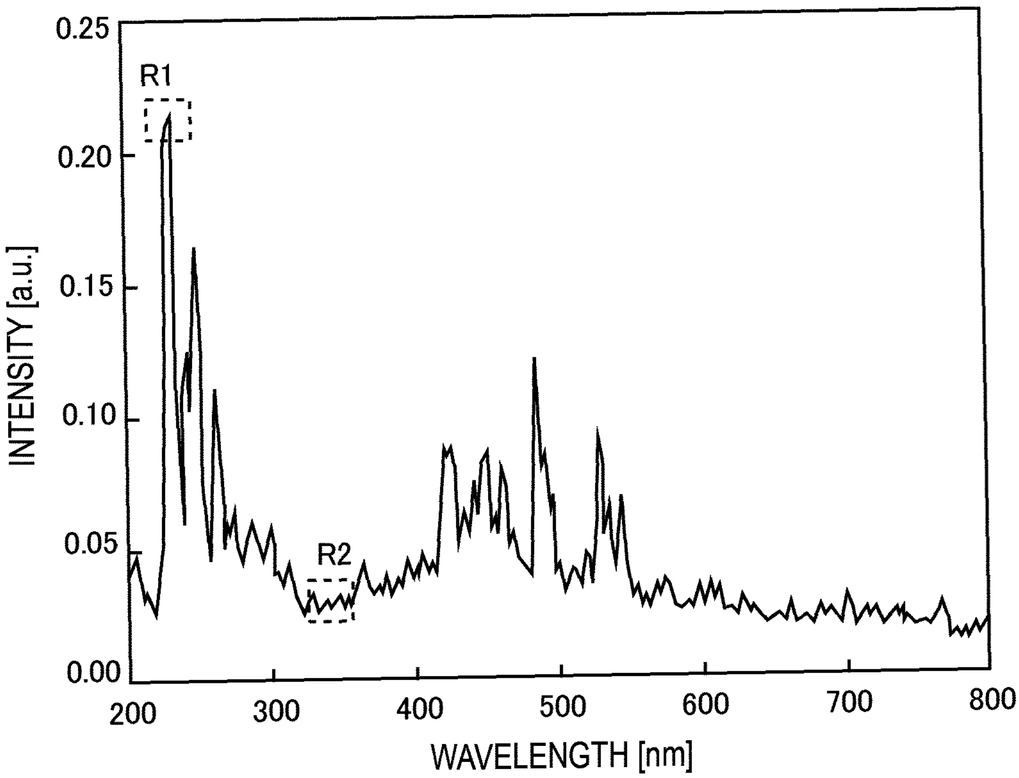
0.25
0.20
0.15
0.10
0.05
0.00
INTENSITY [a.u.]
R1
R2
200
300
400
500
600
700
800
WAVELENGTH [nm]

FIG.2

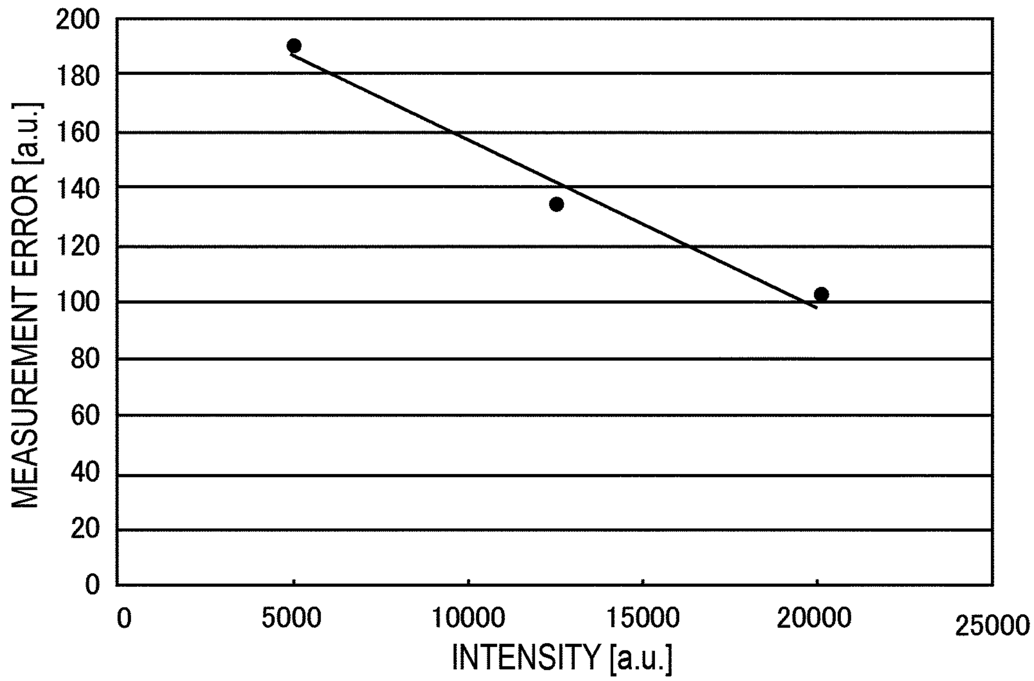
200
180
160
140
120
100
80
60
40
20
0
MEASUREMENT ERROR [a.u.]
0
5000
10000
15000
20000
25000
INTENSITY [a.u.]

FIG.3

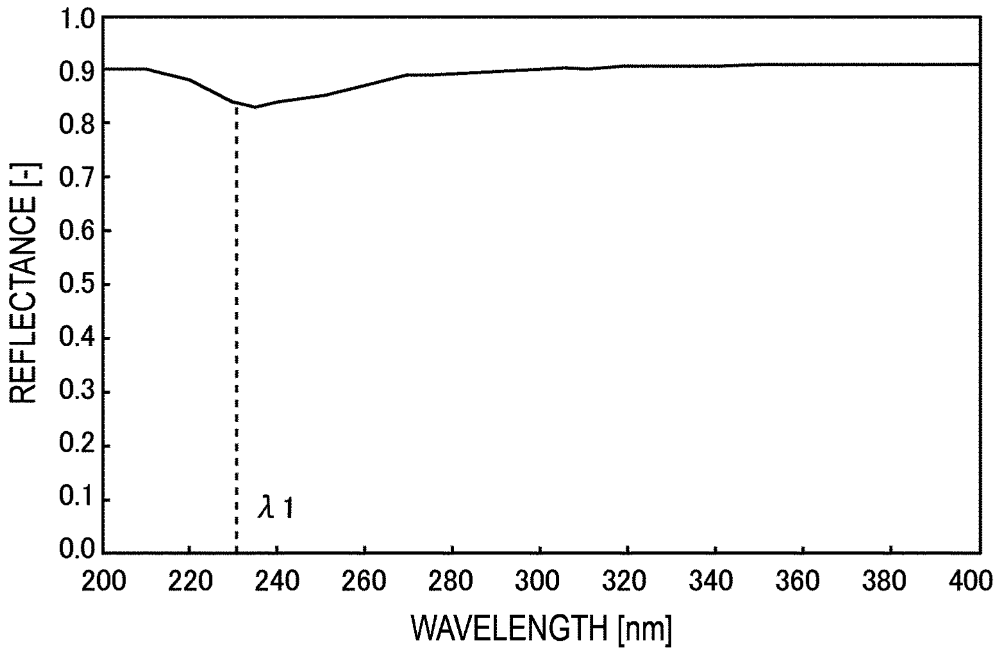
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
REFLECTANCE [-]
λ1
200
220
240
260
280
300
320
340
360
380
400
WAVELENGTH [nm]

FIG.4

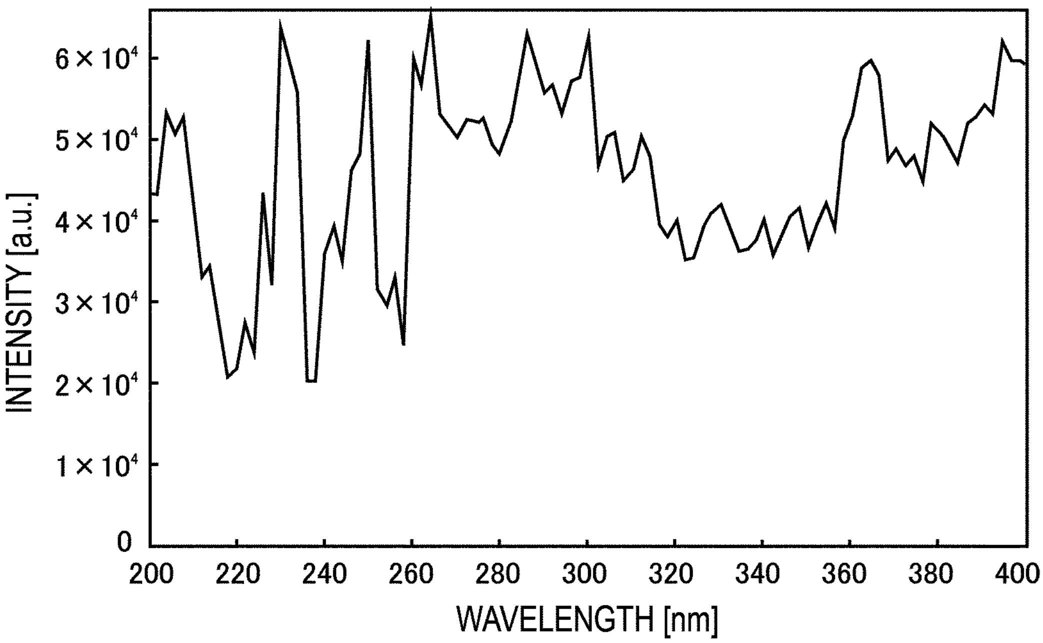
6×10⁴
5×10⁴
4×10⁴
3×10⁴
2×10⁴
1×10⁴
0
INTENSITY [a.u.]
200 220 240 260 280 300 320 340 360 380 400
WAVELENGTH [nm]

FIG.5

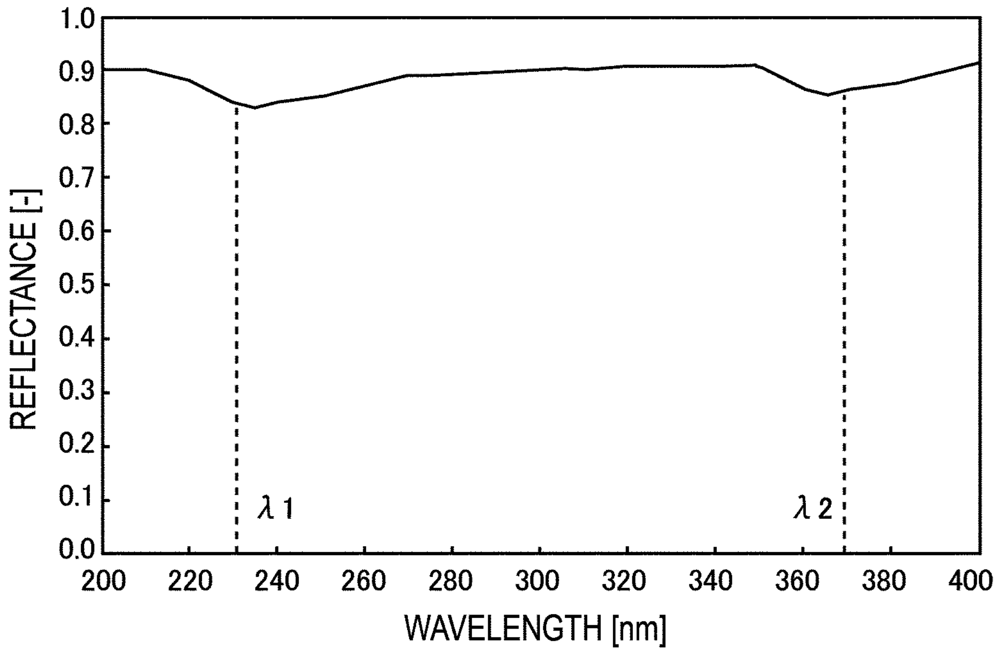
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
REFLECTANCE [-]
λ1
λ2
200
220
240
260
280
300
320
340
360
380
400
WAVELENGTH [nm]

FIG.6

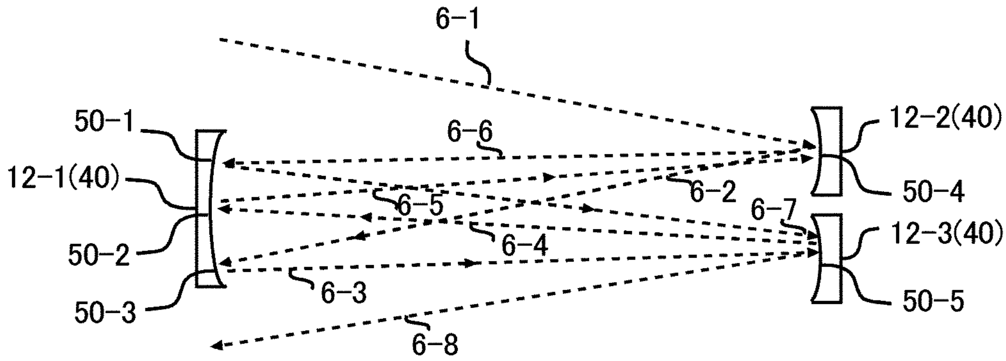

FIG.7

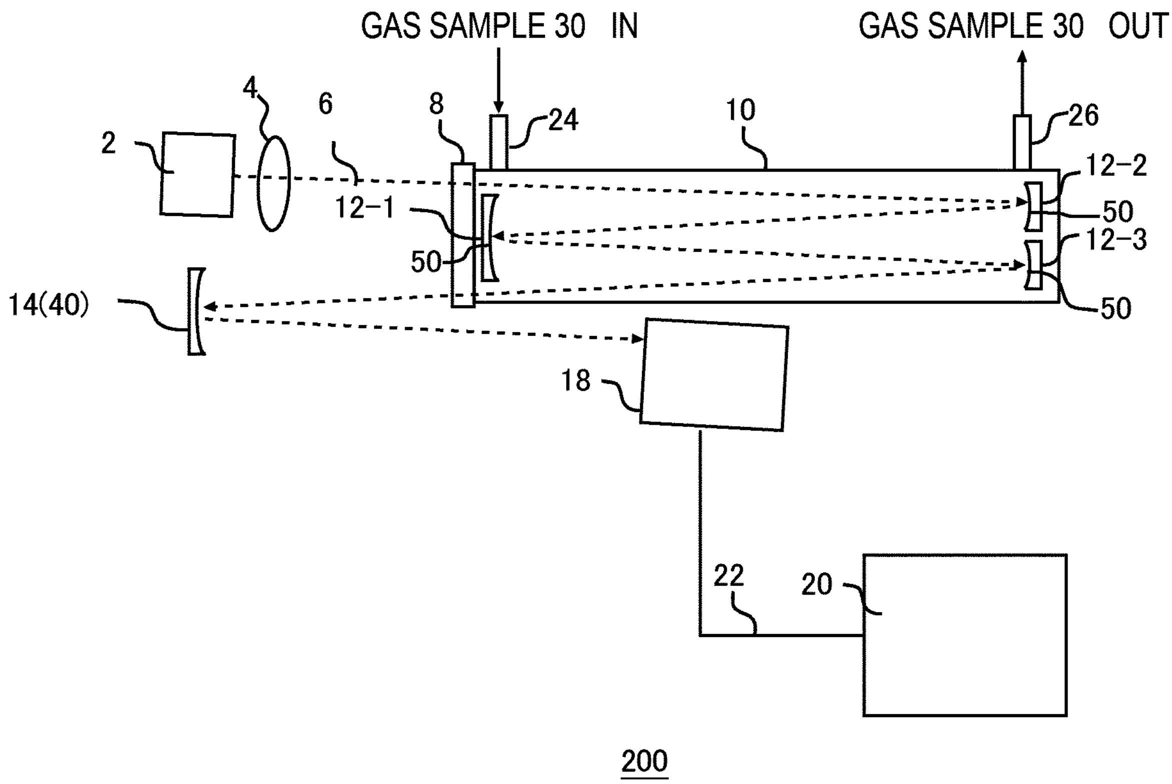
GAS SAMPLE 30 IN
GAS SAMPLE 30 OUT
2
4
6
8
24
10
26
12-2
12-1
50
12-3
50
50
14(40)
18
22
20
200

FIG.8

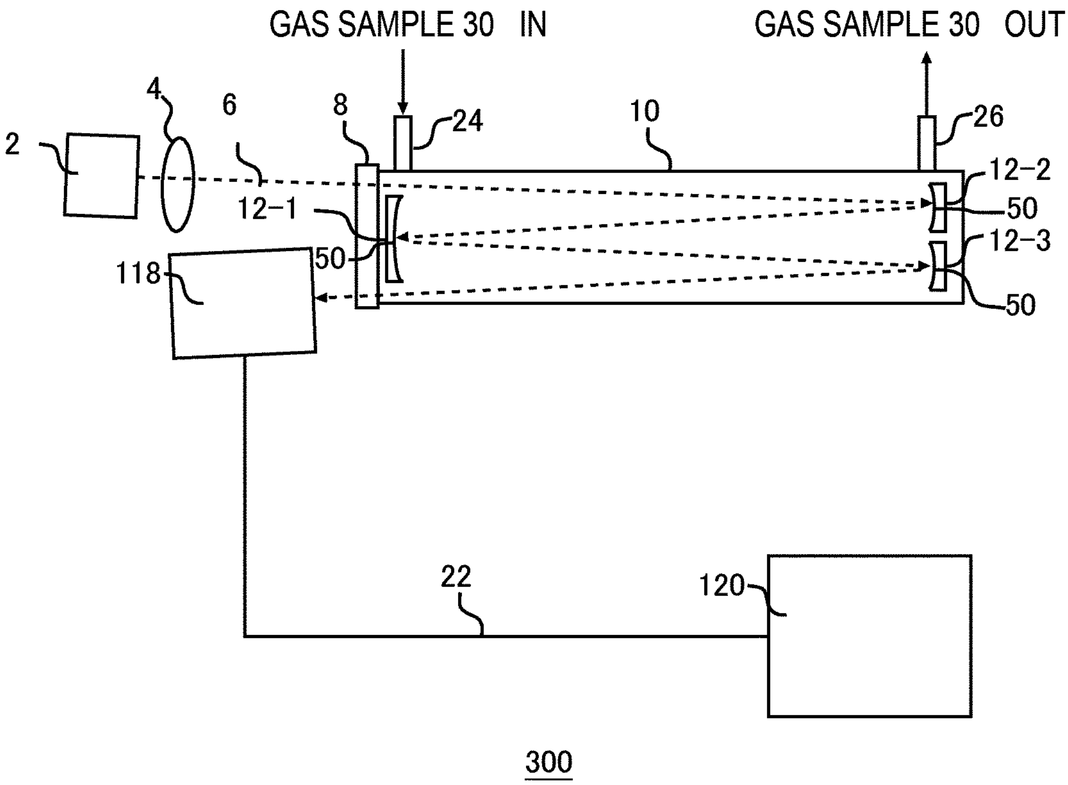
GAS SAMPLE 30 IN
GAS SAMPLE 30 OUT
2
4
6
8
24
10
26
12-2
50
12-1
50
12-3
118
50
22
120
300

FIG.9

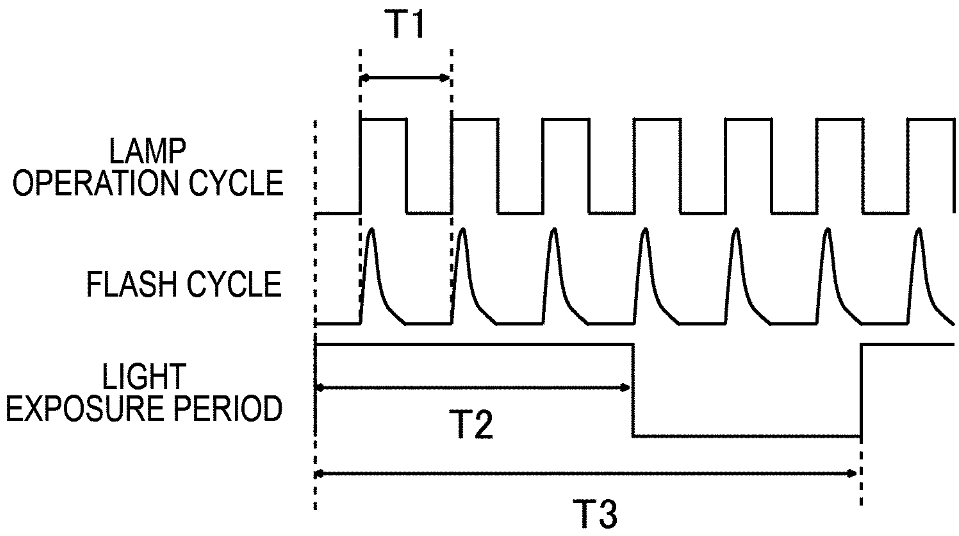
T1
LAMP
OPERATION CYCLE
FLASH CYCLE
LIGHT
EXPOSURE PERIOD
T2
T3

FIG.10

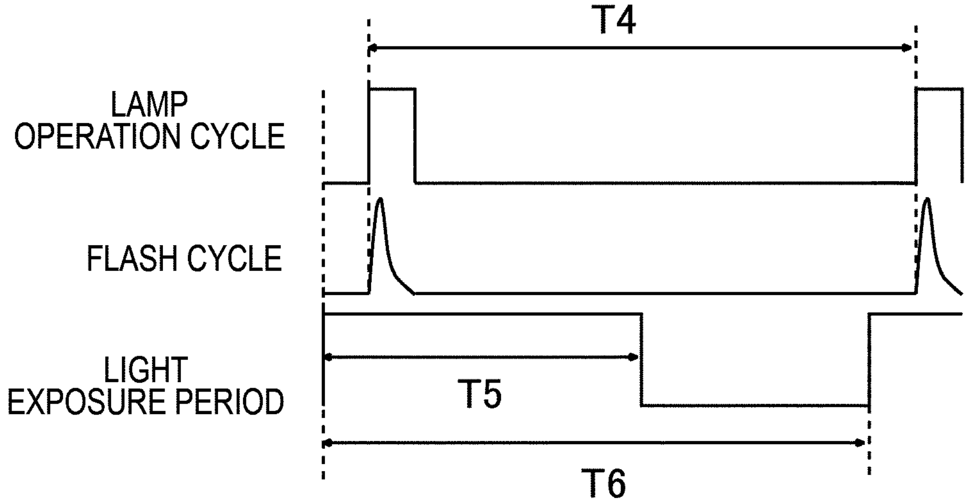
T4
LAMP
OPERATION CYCLE
FLASH CYCLE
LIGHT
EXPOSURE PERIOD
T5
T6

FIG.11

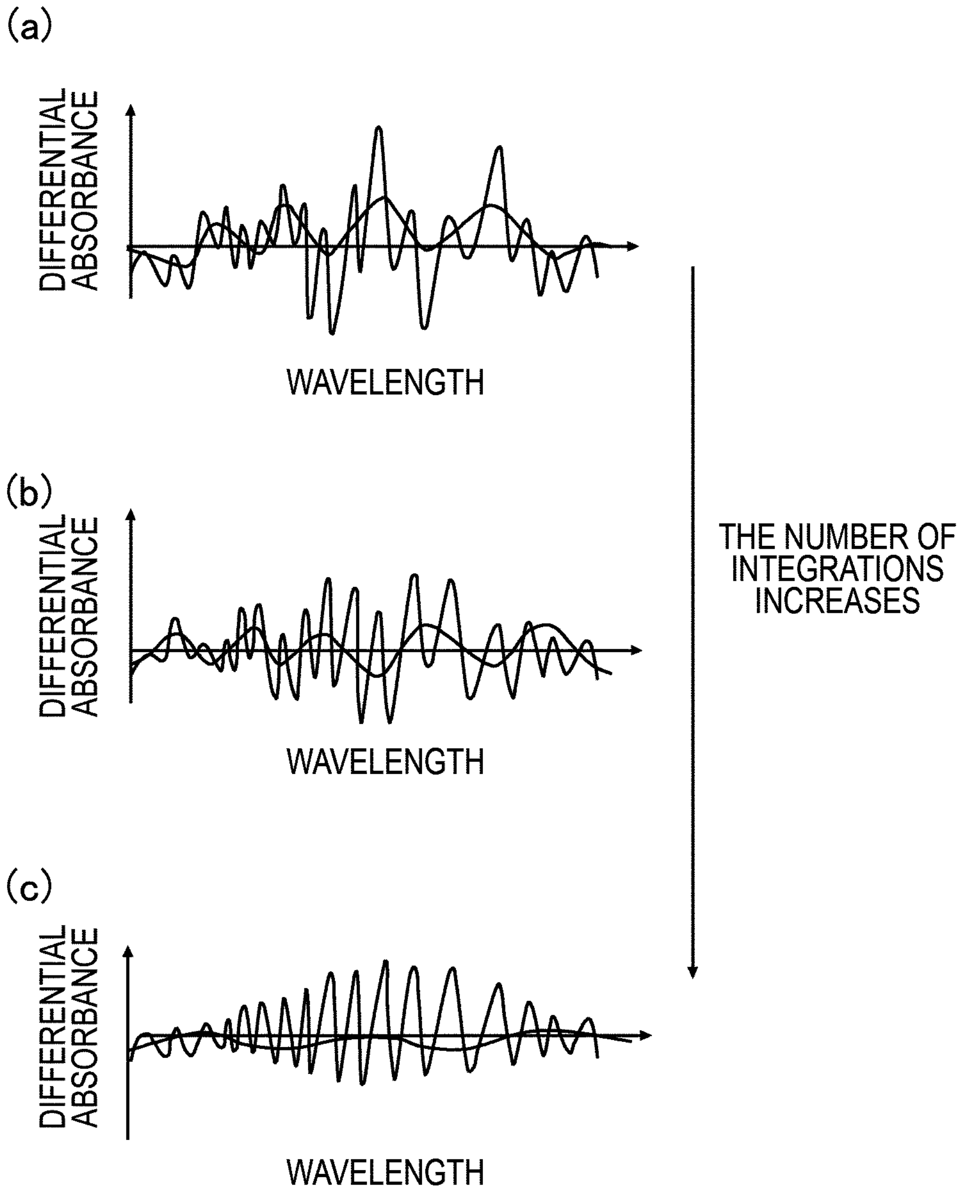
(a)
DIFFERENTIAL ABSORBANCE
WAVELENGTH
(b)
DIFFERENTIAL ABSORBANCE
WAVELENGTH
(c)
DIFFERENTIAL ABSORBANCE
WAVELENGTH
THE NUMBER OF INTEGRATIONS INCREASES

FIG.12

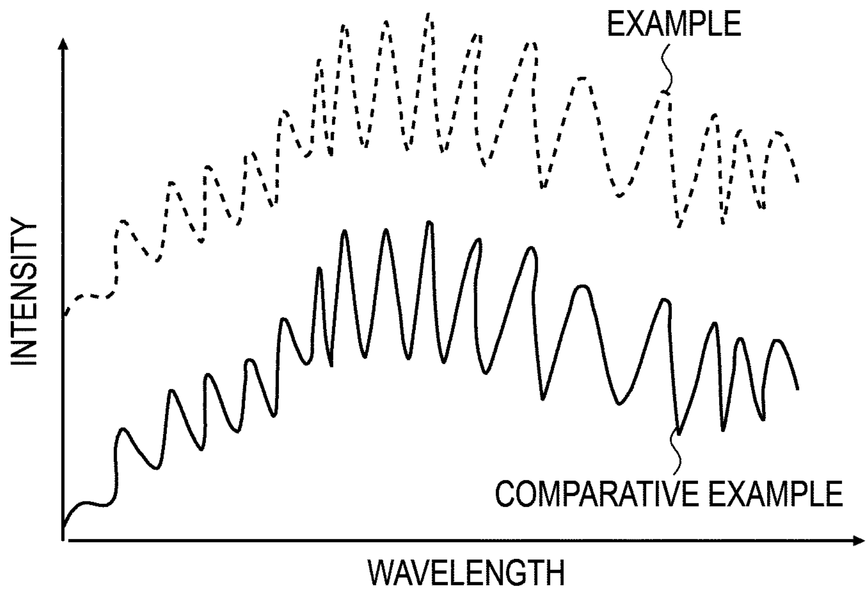

FIG.13

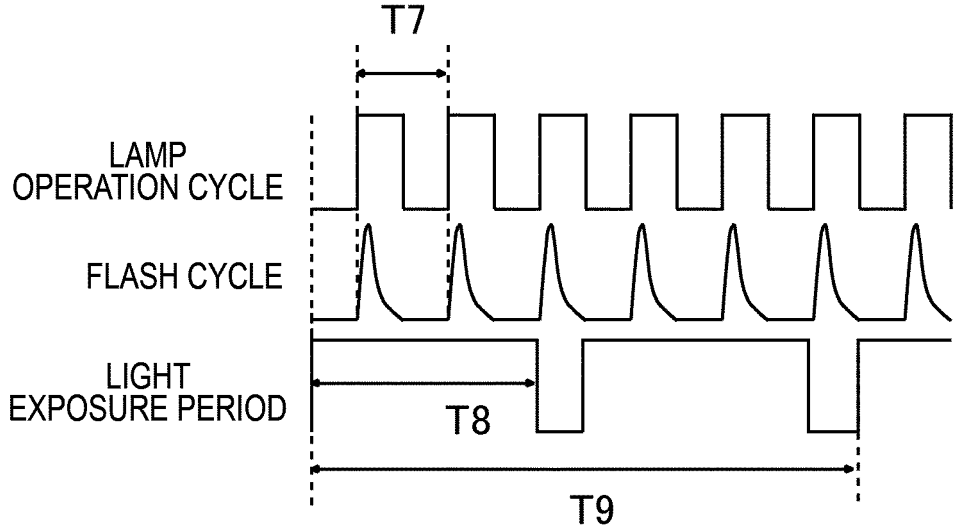
T7
LAMP
OPERATION CYCLE
FLASH CYCLE
LIGHT
EXPOSURE PERIOD
T8
T9

FIG.14

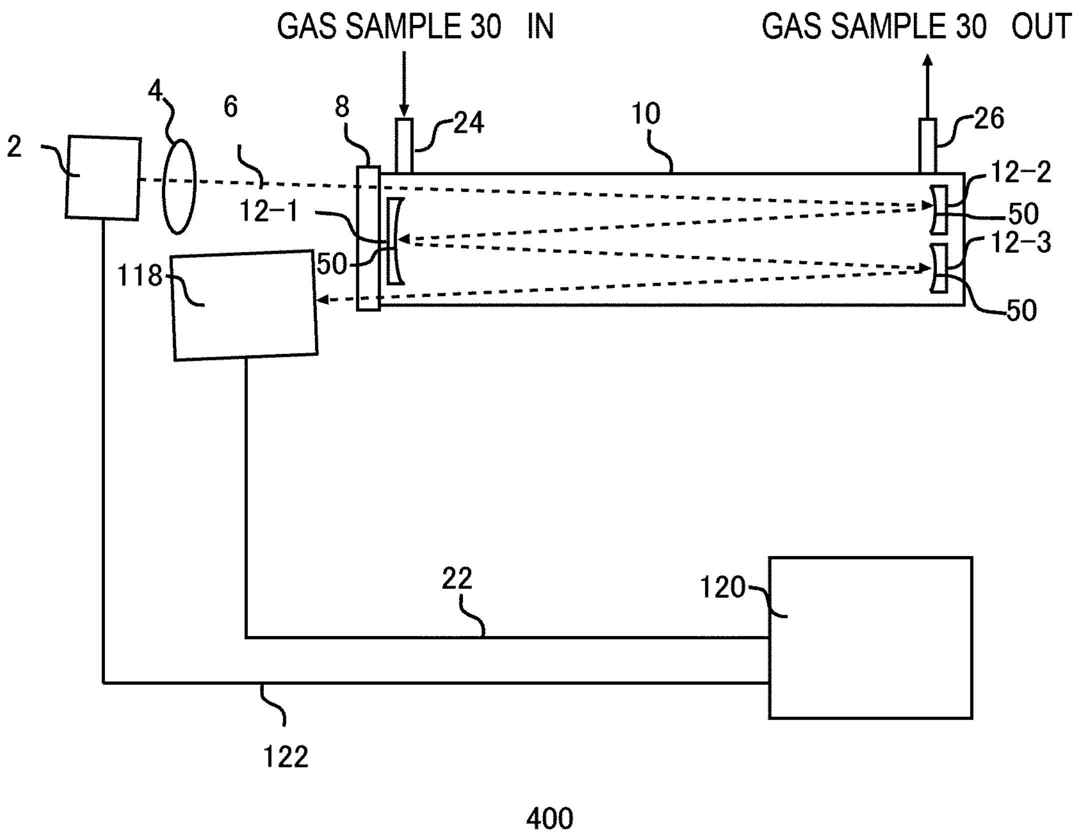
GAS SAMPLE 30 IN
GAS SAMPLE 30 OUT
2
4
6
8
24
10
26
12−2
12−1
50
12−3
50
118
50
22
120
122
400

FIG.15

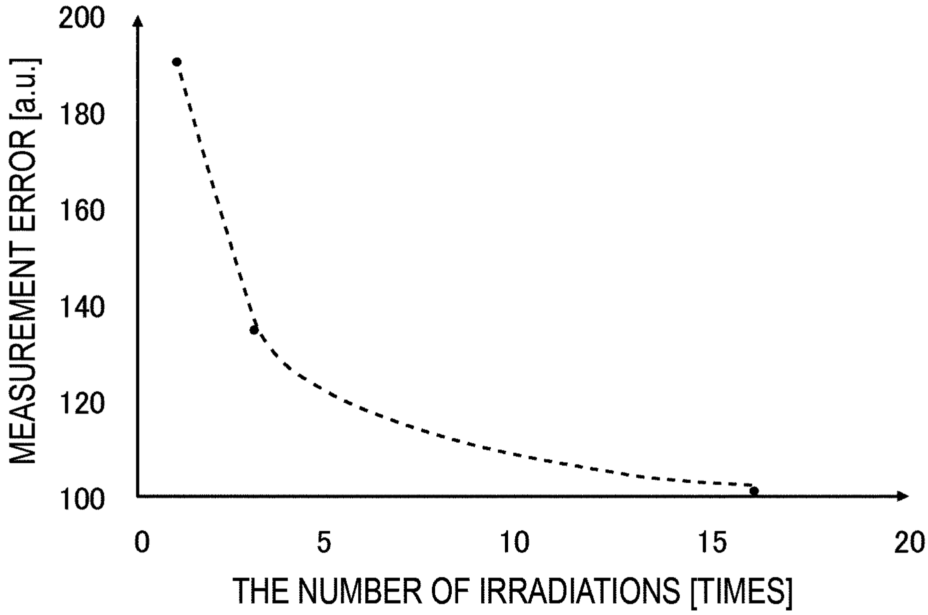
200
180
160
140
120
100
MEASUREMENT ERROR [a.u.]
0
5
10
15
20
THE NUMBER OF IRRADIATIONS [TIMES]

FIG.16

INTERNATIONAL SEARCH REPORT

International application No. **PCT/JP2021/032183**

A. CLASSIFICATION OF SUBJECT MATTER

G01N 21/03(2006.01)i; ***G01N 21/33***(2006.01)i
FI: G01N21/33; G01N21/03 B

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01N21/03; G01N21/33

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 62-257045 A (ANRITSU CORP) 09 November 1987 (1987-11-09) pp. 4-5, fig. 1-3, 5	1-2, 5
X	JP 2005-156329 A (MATSUSHITA ELECTRIC WORKS LTD) 16 June 2005 (2005-06-16) paragraphs [0020]-[0066], fig. 1-19	1
Y	paragraphs [0020]-[0066], fig. 1-19	1-2, 5
Y	JP 2004-138520 A (MITSUBISHI HEAVY IND LTD) 13 May 2004 (2004-05-13) paragraphs [0021]-[0026], fig. 4	2, 5
Y	JP 2003-14634 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD) 15 January 2003 (2003-01-15) paragraphs [0025]-[0035], fig. 1	6-9, 12-13
Y	JP 9-43141 A (SUMITOMO ELECTRIC IND LTD) 14 February 1997 (1997-02-14) paragraphs [0007]-[0011], [0021]-[0063], fig. 1, 16	6-9, 12-13
A	JP 10-318881 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD) 04 December 1998 (1998-12-04)	1-13

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 November 2021	**22 November 2021**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/032183

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 184199/1982 (Laid-open No. 87653/1984) (FUJI ELECTRIC MANUFACTURING CO., LTD.) 13 June 1984 (1984-06-13)	1-13
A	JP 2016-211936 A (RICOH CO LTD) 15 December 2016 (2016-12-15)	1-13
A	JP 2005-315711 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD) 10 November 2005 (2005-11-10)	1-13
A	US 6710347 B1 (SENSORS, INC.) 23 March 2004 (2004-03-23)	1-13
A	US 8654334 B1 (LOS GATOS RESEARCH) 18 February 2014 (2014-02-18)	1-13

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No. **PCT/JP2021/032183**

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Document 2: JP 2005-156329 A (MATSUSHITA ELECTRIC WORKS LTD) 16 June 2005 (2005-06-16) paragraphs [0020]-[0066], fig. 1-19

Claims are classified into the following two inventions.

Invention 1: Claims 1-5
Invention 2: Claims 6-13

Document 2 discloses a "gas analyzer for measuring a concentration of components to be measured which are contained in a sample gas, the gas analyzer comprising:
a light source unit for emitting light that includes an absorption wavelength of the components to be measured;
a cell for encapsulating the sample gas;
a light receiving element for acquiring an emission spectrum of the light that has passed through the cell;
a signal processing circuit for processing a light reception signal of the light receiving element and measuring the concentration of the components to be measured; and
an adjustment unit disposed on an optical path from the light source unit to the light reception element and adjusting characteristics of the light for wavelengths of the emission spectrum." Accordingly, claim 1 lacks novelty in light of document 2, and thus does not have a special technical feature.

Claim 2 dependent on claim 1 has a special technical feature of a "gas analyzer for measuring a concentration of components to be measured which are contained in a sample gas, the gas analyzer comprising:
a light source unit for emitting light that includes an absorption wavelength of the components to be measured;
a cell for encapsulating the sample gas;
a light receiving element for acquiring an emission spectrum of the light that has passed through the cell;
a signal processing circuit for processing a light reception signal of the light receiving element and measuring the concentration of the components to be measured; and
an adjustment unit disposed on an optical path from the light source unit to the light reception element and adjusting characteristics of the light for wavelengths of the emission spectrum,
wherein a reflection mirror is disposed inside the cell so that the light introduced in the cell is reflected several times inside the cell, and
the adjustment unit is the reflection mirror."

Also, claims 3-5 are dependent on claim 2 and have the same technical feature as claim 2.
Thus, the invention in claims 1-5 is classified as invention 1.

Claim 6 does not have a special technical feature identical or corresponding to that of claim 1 classified as invention 1.
Claim 6 has the special technical feature of a "gas analyzer for measuring a concentration of components to be measured which are contained in a sample gas, the gas analyzer comprising:
a light source unit for emitting light that includes an absorption wavelength of the components to be measured;
a cell for encapsulating the sample gas;
a light receiving element for receiving an emission spectrum of the light that has passed through the cell and outputting a light reception signal; and
a signal processing circuit for measuring the concentration of components to be measured, on the basis of the at least one light reception signal which is outputted by the light reception element according to the light incident to the light receiving element during a predetermined measurement period of time,
wherein the measurement period of time is a period of time including at least two times of light emission of the light source unit."
Accordingly, claim 6 and claims 7-13 dependent on claim 6 are classified as invention 2.

Form PCT/ISA/210 (continuation of first sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/032183

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☑ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/032183

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 62-257045 A	09 November 1987	DE 3714346 A1 columns 11-17, fig. 1-4	
JP 2005-156329 A	16 June 2005	(Family: none)	
JP 2004-138520 A	13 May 2004	(Family: none)	
JP 2003-14634 A	15 January 2003	(Family: none)	
JP 9-43141 A	14 February 1997	(Family: none)	
JP 10-318881 A	04 December 1998	(Family: none)	
JP 59-87653 U1	13 June 1984	(Family: none)	
JP 2016-211936 A	15 December 2016	(Family: none)	
JP 2005-315711 A	10 November 2005	(Family: none)	
US 6710347 B1	23 March 2004	WO 2003/078961 A2	
US 8654334 B1	18 February 2014	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2001188043 A **[0003]**